

Sugar Platform

(BioEnergy Initiative Approach)

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Outline

- What is a “Sugar Platform”?
- Why is it Possible?
- Process Opportunities
- Products and Costs from Sugar
- Lignin Upgrading Opportunities
- Summary

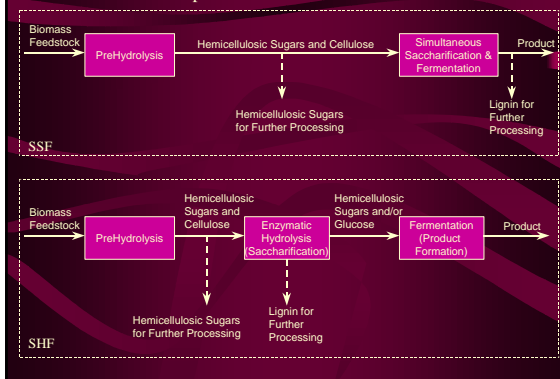
What is a “Sugar Platform”?

- A natural intermediate of ethanol production is the production of pentose and hexose sugars and relatively pure lignin
 - base model converts sugar to ethanol and lignin to power & steam
 - Program recognizes that sugar and lignin can be converted to other higher value products that may help jump start biomass conversion
 - Program is interested in supporting such utilization of biomass sugars to advance the core biomass hydrolysis technology

What is a “Sugar Platform”? (Continued)

- Replace the Simultaneous Saccharification and Fermentation with Sequential Hydrolysis and Fermentation
- Decoupling of Hydrolysis and Fermentation offers various processing advantages and opportunities
- Can serve existing sugar markets, as well as supply sugar for fermentations

Comparisons SSF and SHF Processes



Why is SHF Possible Now?

- Modern metabolic engineering tools have improved its viability
- Enzymatic conversion of cellulose is generally product inhibited by Cellobiose
- With genetically engineered enzymes systems:
 - β -Glucosidase can be increased
 - β -Glucosidase removes the cellobiose and minimizes the product inhibition

Opportunities with a Sugar Intermediate Stream

- By decoupling hydrolysis and fermentation, the cellulase enzyme and the fermentation organism no longer have to operate under the same conditions
 - Enzymes can operate at high temperature for increased performance
 - Microorganisms can operate at moderate temperatures with emphasis on performance in hostile chemical environments and utilization of sugars
- Microorganism could potentially be recycled in no-solids fermentation
- Sugar is available for production of Higher Value Products

Higher Value Products from Sugar Stream

	Market MM lb/yr	Price \$/lb	Yield lb/ton	Fraction of Market**	Revenue*** MM \$/yr
Ethanol*	83,600	\$ 0.15	593	0.5%	\$ 68
Acetic Acid	3,400	\$ 0.33	574	13%	\$ 146
Butyraldehyde	2,100	\$ 0.43	287	11%	\$ 95
Adipic Acid	1,600	\$ 0.65	860	41%	\$ 431
Butanol	1,000	\$ 0.41	287	22%	\$ 91
Acrylic Acid	1,000	\$ 0.69	918	71%	\$ 488
Succinic Acid	600	\$ 0.35	998	128%	\$ 210
Propylene Glycol	600	\$ 0.58	310	40%	\$ 138
Glycerol	350	\$ 0.58	574	126%	\$ 203
Citric Acid	350	\$ 0.82	998	220%	\$ 287
Propionic Acid	100	\$ 0.41	528	406%	\$ 41
Butyric Acid	30	\$ 0.48	436	1119%	\$ 14
Malic acid	15	\$ 0.81	642	3297%	\$ 12
2,3-butanediol		\$ 0.90	379		

* Assuming 10% of Gasoline Market

** Based on one 2000 T biomass/day plant

*** Based on one 2000 T biomass/day plant or 100% of Market

Cost of Sugar Production

- Sugar production from biomass is projected to be:
 - Near Term 6.4¢ to 5.7¢ per lb
 - 2005 4.4¢ per lb
 - 2010 3.9¢ to 3.0¢ per lb
- This compares favorably with current costs of glucose:
 - ~6¢ per lb (estimated corn wet mill)

Upgrading Lignin

- Lignin from either process can be:
 - Burned to produce steam and electricity
 - Depolymerized and hydrotreated to yield aromatic fuel additives
 - Chemically converted to fuel additives
 - Converted to other valuable chemicals
 - Gasified for power production
 - Gasified for fermentation

Higher Value Products from Lignin Stream

- Fuel Additives
 - Market 25% of the gasoline pool - (4 billion gal/yr)
 - Value: 82 ¢ to 99¢ per gallon
 - Potential of 125 gal/ton of lignin
 - 10 to 35 gal/ton of biomass feedstock
 - \$ 7 MM to \$25 MM/yr revenue (2000 T/d biomass)

Higher Value Products from Lignin Stream

	Market MM lb/yr	Price \$/lb	Fraction of Market*	Revenue** MM \$/yr
Surfactants for Oil Rec.	15,000	\$0.67	3%	\$ 8
Charcoal	1,600	\$0.16	26%	\$ 18
Lignin Surfactants	1,000	\$0.12	42%	\$ 21
Activated Carbon	240	\$1.04	173%	\$ 433
Antraquinone	133	\$4.00	313%	\$ 1,663
Hydroquinone	37	\$2.16	1124%	\$ 899
Lignin Available Min	125			
Lignin Available Max	416			

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Summary

- Focusing on a “Sugar Platform” will:
 - Allow independent optimization of hydrolysis and fermentation
 - Attract near term industrial partners
 - Facilitate near-term commercialization of sugar products
 - Ethanol production from sugar is a known art

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